ORIGINAL ARTICLES

DURAL DEFECTS: HOW IMPORTANT IS THEIR SURGICAL REPAIR*†

AN EXPERIMENTAL AND CLINICAL STUDY UPON HETEROPLASTIC AND AUTOPLASTIC DURAL GRAFTS

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DISCUSSION *by Edmund J. Morrissey, M. D., San Francisco; Frederick Leet Reichert, M. D., San Francisco; Howard W. Fleming, M. D., San Francisco.*

DURAL defects caused by trauma, or produced by the removal of tumors of the brain, or the excision of cerebral scars, may or may not be repaired. If these defects are to be repaired, direct closure of the dura by suture, or the use of heteroplastic or autoplastic grafts may be utilized.

Various reasons have been advanced for the use of dural grafts. The earlier investigators were firm believers that the insertion of a graft prevented the formation of adhesions, and thus were a large factor in the prevention of posttraumatic epilepsy.

At the present time, the closure of dural defects by the use of grafts is a question for surgical debate. It is believed by some that a dural graft is entirely unnecessary, and at times may even be harmful because of its foreign body reaction, and its aid in the formation of excessive adhesions.

POINTS IN FAVOR OF DURAL GRAFTS

Those who favor the use of dural grafts quote the following reasons for their usefulness: (1) the prevention of rough edges of bone irritating the brain; (2) to close a dural defect after the removal of a large meningioma, or a cerebral scar and thus prevent surface adhesions; (3) to form a watertight closure after the removal of tumors or scar, provided the ventricle has been opened; (4) to prevent the formation of a brain fungus following depressed fractures or tumors, provided the intracranial pressure is high; (5) to prevent the development of meningitis following depressed fractures, which could arise secondarily from an infected scalp; (6) to form a definite layer over the surface of the brain so that, in cases of depressed fracture, fragments of the bone removed may be inserted in place to form a bony union.

AUTHORS' STUDIES

For the purpose of determining whether a dural graft is necessary, and to further determine if a dural graft is to be utilized, whether a heteroplastic or an autoplastic graft is more suitable, a series of twenty-four operations were carried out upon dogs, and a small series of clinical cases were studied. In this group of experiments the relative merit of dural repair was studied by the use of fascia lata, animal membrane, and a blank dural opening. These animals were operated upon under aseptic technique. The temporal muscle was stripped away from the calvarium under anesthesia, and a half-inch by one-inch opening was made in the skull. The dura was not injured. An area of dura of approximately the same size was then resected, without injury to the underlying arachnoid. This dural opening was left intact in a certain proportion of these animals, and in others a piece of fascia lata or animal membrane was sutured in place. The animal membrane utilized was sheep intestine which had been sterilized and tubed. These animals were observed for a period of twenty-four hours to one year.

EMBRYONIC BACKGROUND

The dura mater develops from the embryonic mesenchyme which early grows out as a covering to the neural tube. The mesenchyme condenses and splits and differentiates into scalp, bone, dura, arachnoid, and pia mater. Over the brain the dura mater is a single dense fibrous membrane, which may be subdivided into a denser outer layer of collagenous fibers, loosely adherent to the skull and serving as periosteum, and an inner looser layer of collagenous and yellow elastic fibers. The venous sinuses of the skull lie between these two layers. At the foramen magnum the outer layer separates from the inner, to become the periosteum of the vertebrae, the inner layer remaining as the dural covering of the spinal cord. The dura mater is loosely held to the inner surface of the skull by prolongations of its fibrous meshwork, and to the arachnoid membrane by delicate tissue bridges. Jordan makes the statement that the dura is rich in lymphatics, but Weed contends that these spaces are not true lymphatics lined with endothelium, but are merely areolae in the dense membrane. The vascularity of the dura mater is attested to by all writers. The large vessels are confined largely to the outer layer, while the vessels of the inner layer are fine and numerous. Hassin describes the dura mater as characterized by lacunae and numerous interstitial spaces containing nests of arachnoid or mesothelial cells. The characteristic cell is the fibroblast, but there may be found also histocytes and plasma cells. The outer layer is said to contain more nuclei than the inner. Where not attached to the bone, the outer layer is covered by a thin endothelioid coat. The inner surface more nearly resembles a true serous surface, being lined by a thicker type of endothelioid cell.

SURGICAL REPAIR OF DURAL DEFECTS

The repair of the dural defects by surgical means was first carried out by Sacchi in 1893. He recommended that the osseous disk of a trephination be turned around so that the periosteum approximated the dural defect. Abbe, in 1895, referred to a patient of Beeches', wherein gold foil had been employed to cover the raw area left after the separation of subdural adhesions. He, however, preferred rubber tissue. Since this pioneer

* From the Pharmacological Laboratory of Prof. C. H. Thienes, University of Southern California, Los Angeles.
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† List of references will appear in the reprints.

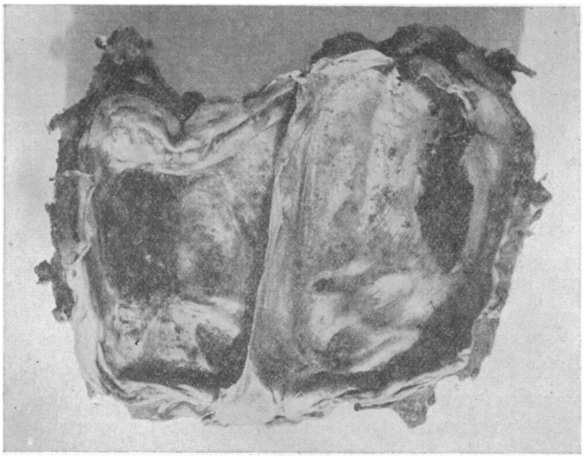


Fig. 1.—A section of the skull has been removed. The dura is seen on its inner aspect. The two cranial defects are visible on both sides. On the right side, animal membrane has been sutured in place. On the left side the dural defect has been left open. Note how the space has been covered by the new growth of dura. It is from these sections that material has been taken for microscopic studies. Time after operation, five weeks.

Fig. 2.—Section taken three days after surgery. Note the thick clot which has formed over the brain and the fascia lata graft at the base of this clot. Microscopic sections were taken directly through this area.

work, many different tissues have been suggested for plastic operations upon the dura. Among those advocated were heteroplastic and autoplastic fascial transplants used alone, or in combination with muscle and fat, skin muscle, splitting of the intact dura, peritoneum, periosteum, amniotic membrane, veins, arteries, hernial sacs, egg membrane, tunica vaginalis, celluloid plates, laminated catgut, dog peritoneum, blood vessels of the calf, and finely scraped intestine of the sheep.

Autoplastic fascial transplant was first introduced by Kirschner, and was also advocated by von Saar, Kleinschmidt, Smirnoff, Denk, von Ebert, Hill, Barany, Gille, Neuhoff, Jeger, Alissandri, Halstead, and Caylor. Peritoneum was first utilized as a dural graft by Kocher and Beresowsky. It was further investigated by von Saar, Kolaczek, Smirnoff, Finsterer, etc. Peritoneal transplants were considered unsatisfactory because of the difficulty in obtaining them and, further, the fact that they adhered quickly to the underlying brain. The use of adipose tissue alone, or in combination with fascia, was utilized by Smirnoff, Rehn, Körte, Marchand, Bode, Koennecke, Drevermann, Byford. The use of periosteal grafts for the filling of cranial and dural defects was first suggested by Sacchi in 1893. This idea was confirmed by researches of Wolf, Koenig, Durante, Rhigetti, von Hacker, Delangenière, and Kerr. Though the primary purpose of the periosteal graft was to cover cranial defect, some attention was paid to regeneration of the underlying dura. Splitting the dura in half was first suggested by Bruning, and was independently described by Elsberg, and also utilized by von Eiselberg and Dobrotvorski. The technical difficulty in dividing the dura prevented its widespread use. The use of celluloid was advocated by Finsterer and von Eiselberg. Penfield and Peet believed the use of celluloid is quite valuable in preventing adhesions of the dura to the overlying scalp, and recommend its use in traumatic cases. Finely scraped intestine of the sheep was advocated by Hanel, and methods for disinfection of this membrane was suggested by Hofmeister and Taddei. Catgut applied in strands and laced into a network has been considered superior to all substance previously utilized, and absolutely prevented adhesions to the underlying brain (Righetti, Dainelli, Caporale, Caporale e Bertini, De Bernardis, Caporale and De Bernardis). Less common substances advocated, and more experimental in nature than practical, were the blood vessels, especially the vena cava, Unger and Bettman; hernial sacs and dog peritoneum, Finsterer; egg membrane, von Saar; tunica vaginalis, Kocher; omentum, Kozireff; viable muscle, Dixon; epithelium, Roux-Berger and Ballance; and umbilical cord by Perimoff. Experimental studies carried out by Trotter, Sayard and Harvey, and Penfield, supplied definite proof that the dura regenerated itself spontaneously, sufficient to cover any traumatic or operative defect.

In spite of the numerous substances suggested to close dural defects, the present consensus of opinion is that the most suitable is autoplastic fascia. If the defect is small, temporal muscle fascia is utilized. If it is large, fascia lata is recommended.

EXPERIMENT PROCEDURES

The experiments were performed upon a series of dogs; the first group, studied from twenty-four hours to one year, consisted of fascial transplants; the second group consisted of animal membrane

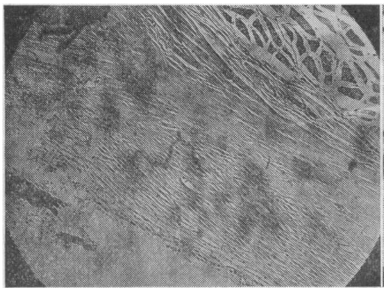
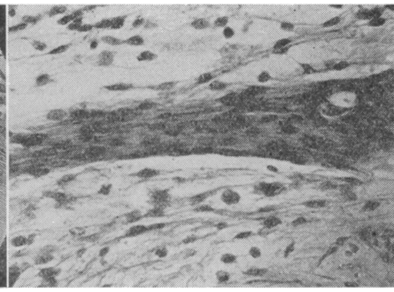


Fig. 3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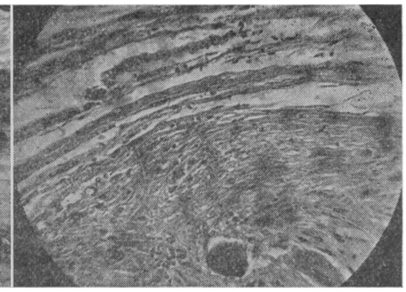
Fig. 5

Fig. 3.—Dura removed. Three months after operation. Thick layer of dura formed; few cells; bone formation at edge.

Fig. 4.—H. G., age thirty-nine, dural defect with the insertion of a graft, six weeks after surgery.

Fig. 5.—High power. Fascia inserted. Five weeks after operation. Note young fibroblasts, foreign body giant cells, plasma cells, and clasmatocytes.

grafts; and in the third group the dural opening was not covered in any way. These animals were sacrificed by intra-arterial formalin injection. The stains utilized in this study consisted of hemotoxylin and eosin; Mallory's phosphotungstic hemotoxylin stain for fibrils; Mallory's aniline blue-orange G stain for the presence of collagen; and Laidlaw's silver stain for reticulin.

Upon gross examination, the muscle was adherent to the newly formed dura. The defect was entirely closed and smoothly healed on the undersurface. In all three sets of experiments, the gross appearance of the newly formed dura was the same. The dura was adherent to the overlying bone, and when the skull was resected came away with the bone, leaving a free, non-adherent brain beneath. There were no adhesions whatsoever to the underlying arachnoid. This, of course, had not been injured. In one case where a small cortical blood vessel had been injured, and in another where an excessive amount of bleeding had occurred over the surface of the brain, small fibrous strands of adhesions were attached to the brain (Fig. 1). Sections taken through the surface of the brain were entirely normal. In those experiments wherein the dural defect was left open, a thin clot was present in the first twenty-four hours, but within a three-day period a thick clot had formed (Fig. 2). In order to study these sections, a wedge of brain and clot were excised through the bony defect, thus preserving the surface of the brain and the clot in one adherent piece.

In the group wherein the dural defect was not replaced, a definite membrane was visible within seven days, which became quite apparent on the tenth day. On microscopic examination, the process of repair consisted of formation of granulation tissue with a definite outgrowth of fibroblast from the muscle and the dural edge. There was no clear indication that there was a transition of the mononuclear cells of the blood. The clasmatocytes, or wandering tissue cells, as well as occasional polyblast, were present (Fig. 3). In a clinical case, the newly formed dura was evident six weeks following surgery, and here again new cell formation seemed to arise from the fibroblasts of the muscle and dura, and not from the blood-clot (Fig. 4).

The second series of animals was followed over a similar period of time. Fascia lata and temporal muscle, however, were utilized to cover the defects. The process again was one of repair with a definite invasion of a similar cell structure, except that foreign body giant cells were in evidence. Within a five months' period, phagocytosis of the fascia had taken place, as well as the laying down of calcium. Within nine months there still was evidence of the fascial membrane, while within a period of a year the presence of calcium was the only indication that foreign body had previously existed (Fig. 5). In a clinical case a similar histological picture was present, and coincided in every detail with the animal experiments (Fig. 6).

In the third series, animal membrane was utilized, which proved to be as satisfactory as the

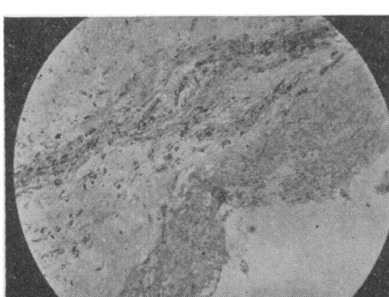
Fig. 6

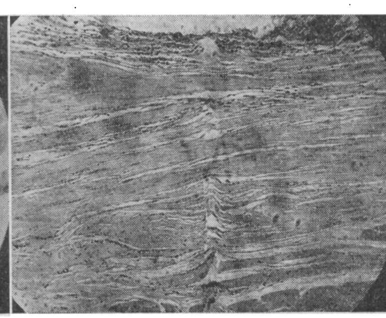
Fig. 7

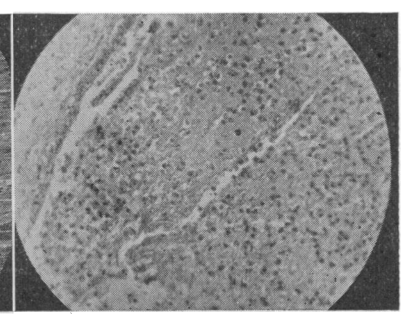
Fig. 8

Fig. 6.—M. L., age ten. Fascial graft five months after insertions.

Fig. 7.—Membrane inserted. One year after operaton. Membrane apparently completely absorbed. Dense layer or dura formed; slight infiltration of small round and plasma cells near pia.

Fig. 8.—R. B., age thirty-six. Animal membrane graft, eight months after surgery.

fascia, both as to its ease in application and the resultant histological picture. The same type of cell took part in the reaction, and at the end of a year complete absorption had occurred (Fig. 7). In a clinical case, studied eight months after the introduction of the graft, the membrane was quite apparent. It was entirely surrounded by fibrous tissue. The dura about the membrane was thicker than the surrounding area, and there were no adhesions (Fig. 8).

CONCLUSIONS

1. Experimental and clinical studies indicate that the use of either a heteroplastic or autoplastic graft for the repair of dural defects is entirely unnecessary.

2. Should one feel inclined to use a dural graft, heteroplastic animal membrane is equally as efficient as autoplastic fascia.

3. Dural defects caused by surgical procedures or depressed skull fractures without injury to the underlying arachnoid spontaneously repair themselves.

4. If the arachnoid is not injured, adhesions will not form between the dura, arachnoid and brain, but will form between the overlying skull and periosteum, as well as fascia and muscle.

5. Both types of grafts are entirely absorbed within twelve months.

6. The cells that form the new dura are apparently derived from the overlying fascia and muscle and from a peripheral outgrowth of dural cells, which arise from the cut margin of the dura.*

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DISCUSSION

Edmund J. Morrissey, M.D. (330 Medical Building, San Francisco).—The work of Doctors Glaser and Thienes is an excellent and timely piece of experimental research. Their findings agree in all important details with similar studies reported by Sayard and Harvey, and Lear and Harvey.

In my opinion, the work shows conclusively that defects in the dura will heal without the formation of adhesions in a very short period of time, provided the underlying arachnoid has not been injured. On the other hand, if the arachnoid has been injured, adhesions will form, regardless.

Too often, however, we see the mistake being made of covering these dural defects with facial transplants, or some other foreign material, which certainly is unnecessary and which, in my opinion, will do nothing more than increase the adhesions.

Frederick Leet Reichert, M.D. (Stanford University Hospital, San Francisco). — This experimental study of Doctors Glaser and Thienes confirms the clinical observations of neurosurgeons that, whether a portion of dura is excised or replaced without suture, the resultant gap is readily and completely closed by tissue which resembles dura and officiates as dura. This applies only where the pia arachnoid is intact.

In the clinical application of this experimental study, one need not be apprehensive about replacing a dural defect if overlying muscle is available; but if muscle cannot be used, a fascial graft or the prepared membrane will form a new dura. Again, this applies in cases in which the pia arachnoid is intact. Where the pia arachnoid is absent from any cause, one prefers to cover this pial defect by a plastic procedure with the patient's dura, leaving a dural defect over the intact pia arachnoid.

* We wish to extend our sincere thanks to Dr. H. M. Beerman for his aid in the experimental surgery, and to Dr. M. Bettin and Dr. E. M. Butt for their advice in the preparation of the pathological material.

Howard W. Fleming, M.D. (384 Post Street, San Francisco).—Doctors Glaser and Thienes's clinical and experimental studies give further substantiation to the popularly accepted theories regarding the healing processes of brain and dural tissues. The facts that dural defects repair themselves spontaneously, and that adhesions do not form if the arachnoid is uninjured, are reassuring.

In the past, surgeons often went to great extremes to effect a complete closure of the dura following operation. This, in most cases, is no longer considered necessary. There are circumstances where the use of a dural graft may be advantageous.

It is advisable to debride and repair penetrating wounds of the brain. If the patient is cared for soon after injury, a careful debridement will lessen the possibility of infection and possibly reduce the morbidity. A snug graft in the dura will minimize the contusion to the brain and prevent a fungus should a marked increase of intracranial pressure develop as a late complication. A careful repair of the dura will also allow the replacement of small fragments of bone to fill the skull defect that could not otherwise be utilized.

In the treatment of post-traumatic epilepsy, excision of a cortical scar and the overlying dura is often necessary. Repair of the dural defect is not essential, but probably advisable. Occasionally, false meningoceles develop in cases where there is a loss of bone over the dural defect.

The kind of material to be used in dural grafts depends largely upon the past experiences and the preferences of the individual surgeon. Many prefer autoplastic substances, such as temporal fascia or fascia lata, on the theory that there is less foreign-body reaction than when heteroplastic substances are used. The author's conclusion in this paper would seem to negate this idea.

Probably careful handling of tissues and hemostasis are more important than the type of material used to fill a dural defect.

TRICHINOSIS*

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Discussion *by John J. Miller, M.D., San Francisco; R. D. Friedlander, M.D., San Francisco; E. M. Butt, M.D., Los Angeles.*

The Mosaic code, of some three thousand years ago, forbade the use of pork: "And the swine is unclean to you. Of their flesh shall ye not eat, and their carcass shall ye not touch."[1] Some believe that it was forbidden because the hog had been worshiped by certain heathen tribes; but modern interpreters[2] of this code maintain that Moses had noticed a peculiar train of symptoms in people who had partaken of pork, and thus condemned its use as food. For thirty centuries the Jews were ridiculed for abstaining from pork. During this time no one heard of trichinosis and, as far as is known, no one, until 1835, saw trichinella. In February of that year James Paget, then a medical student at St. Bartholomew's Hospital, London, "was dissecting the muscles of a subject, when his scalpel became quickly and repeatedly blunt."[3] He saw numerous small calcareous specks in the muscles. There was no microscope available at the hospital, but Robert Brown, the botanist, had a simple one at the British Museum through which Paget saw a worm within a capsule. He made careful sketches of the parasite, and prepared a report of his discovery for the *London Medical Gazette*;

* From the Department of Pathology, Stanford University School of Medicine.

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